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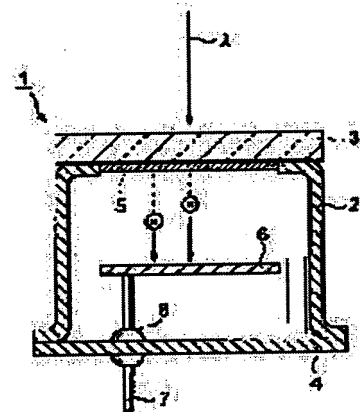
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(54) PHOTO-DETECTING TUBE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a photo-detecting tube which selectively detects only the light of wavelength near 360 nm.

SOLUTION: A photo-detecting tube 1 is provided with an incidence window 3 and a photocathode 5, the incidence window 3 is made of covar glass, and the photocathode 5 is made of GaN. The covar glass selectively transmits the light of wavelength \geq about 290 nm, and the GaN selectively and photoelectrically converts the light of wavelength \leq about 430 nm. Thus, in the photo-detecting tube, the peak of detecting sensitivity lies in wavelength 360 nm, and only the light of wavelength $360 \pm$ about 70 nm can be selectively detected without an optical band-pass filter.



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CLAIMS

[Claim(s)]

[Claim 1] It is photodetection tubing characterized by for said entrance window consisting of cover glass, and said photoelectric cathode consisting of GaN in photodetection tubing equipped with the entrance window which makes some vacuum housing outer walls, and the photoelectric cathode which carries out photo electric conversion of the light which has been arranged in said vacuum housing and penetrated said entrance window.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to photodetection tubing, such as the photoelectric tube and the photomultiplier tube.

[0002]

[Description of the Prior Art] Conventionally, the photodiode using Semi-conductor Si as a photodetector which measures the optical reinforcement of the light source is known. Moreover, photodetection tubing, such as the photomultiplier tube, is known as a photodetector which performs photodetection of high sensitivity.

[0003]

[Problem(s) to be Solved by the Invention] However, in above-mentioned photodetection tubing, when acting as the monitor of the reinforcement of the light source which carries out outgoing radiation of the ultraviolet radiation near the wavelength of 360nm, it needed to use together the light filter which has the permeability property of making only the specific wavelength penetrating. That is, the light filter which has 1 or two or more specific wavelength light selection transparency properties ahead [photodetection tubing] in the conventional photodetection tubing has been arranged, and the light which penetrated this was detected. While such a light filter decreased the reinforcement of the transmitted light, it had caused the increment in components mark. This invention is made in order to solve such a technical problem, and it aims at offering photodetection tubing which detects only the light near the wavelength of 360nm alternatively.

[0004]

[Means for Solving the Problem] In photodetection tubing equipped with the photoelectric cathode which carries out photo electric conversion of the light which photodetection tubing concerning this invention has been arranged the entrance window which makes some vacuum housing outer walls, and in a vacuum housing, and penetrated the entrance window, it is characterized by for an entrance window consisting of covar glass, and photoelectric cathode consisting of GaN. Covar glass makes light with a wavelength of about 290nm or more penetrate alternatively, and GaN carries out photo electric conversion of the light with a wavelength of about 430nm or less alternatively. therefore, this photodetection tubing -- setting -- wavelength 360nm**-- only about 70nm light can be detected alternatively, without using an optical band pass filter.

[0005]

[Embodiment of the Invention] Hereafter, photodetection tubing concerning the gestalt of operation is explained. The explanation which overlaps using the same sign is omitted to the element which has the same element or the same function.

[0006] Drawing 1 is drawing of longitudinal section of the photodetection tubing 1 concerning the gestalt of operation. This photodetection tubing 1 is the photoelectric tube, and is equipped with the vacuum housing which closes upper limit opening of the metal by-pass 2 with the face-plate 3 as an entrance window, and comes to close lower limit opening with the stem plate 4. The interior of this vacuum housing is decompressed rather than atmospheric pressure. In this vacuum housing, the photoelectric cathode 5 which carries out photo electric conversion of the light λ which penetrated the entrance window 3, and the metal anode plate 6 which collects the electrons e emitted from photoelectric cathode 5 are arranged.

[0007] Photoelectric cathode 5 is formed in the inside of an entrance window 3, predetermined potential is given to photoelectric cathode 5 through a by-pass 2, and potential higher than cathode 5 is given to an anode plate 6. For example, if photoelectric cathode 5 is grounded and the potential of 100V is given to an anode plate 6, the electric field which pull Electron e in the anode plate 6 direction inside a vacuum housing according to the electrical potential difference between these will occur. After being accelerated according to an internal field, the electron e generated in photoelectric cathode 5 according to the incidence of Light λ collides with an anode plate 6, and is taken out outside as the output current through the lead pin 7 electrically connected to the anode plate 6. In addition, the hermetic seal of the clearance between the lead pin 7 and the stem plate 4 is carried out by the charge 8 of a glass reinforcement.

[0008] Drawing 2 is a graph which shows a wavelength-entrance window permeability (%) property, a wavelength-photoelectric-cathode radiant sensitivity (mA/W) property, and the detection sensitivity (mA/W) property of photoelectric-tube 1 the very thing which compounded these. The component beyond wavelength λ_{a1} penetrates an entrance window 3 among the light λ which carried out incidence to the entrance window 3. Moreover, photo electric conversion of the component not more than wavelength λ_{a2} is carried out by photoelectric cathode 5 among the light λ which carried out incidence to photoelectric cathode 5. Wavelength λ_2 is longer than wavelength λ_1 , therefore photoelectric-tube 1 the very thing has detection sensitivity between wavelength λ_{a1} - λ_{a2} .

[0009] In addition, the permeability in the wavelength λ_1 of an entrance window 3 is or less about 1 of the permeability in wavelength $\lambda_{a1}+140\text{nm} / 1000$, and the radiant sensitivity in the wavelength λ_2 of photoelectric cathode 5 is or less about 1 of the radiant sensitivity in wavelength $\lambda_{a2}-140\text{nm} / 1000$.

[0010] The photoelectric tube 1 concerning the gestalt of this operation is equipped with the entrance window 3 which makes some vacuum housing outer walls, and the photoelectric cathode 5 which carries out photo electric conversion of the light λ which has been arranged in a vacuum housing and penetrated the entrance window 3, and an entrance window 3 consists of covar glass, and photoelectric cathode 5 consists of GaN. Covar glass makes the light more than the wavelength of about 290nm (= λ_1) penetrate alternatively, and GaN carries out photo electric conversion of the light below the wavelength of about 430nm (= λ_2) alternatively. therefore, this photoelectric tube -- setting -- near the wavelength of 360nm -- the peak of detection sensitivity -- having -- wavelength 360nm**-- only about 70nm light can be detected alternatively, without using an optical band pass filter. moreover, wavelength 360nm**which gives the peak value of the detection sensitivity of this photoelectric tube -- each detection sensitivity in about 70nm is or less about 1 of the detection sensitivity of peak value / 1000. Moreover, the detection sensitivity in the wavelength of 254nm of this photoelectric tube is or less about 1 of the detection sensitivity of peak value / 1000, and can detect light with a wavelength [of a mercury lamp] of 360nm in distinction from light with a wavelength of 254nm. In addition, the cobber hard glass (KB hard glass) by NEC Vacuum Glass company was used for this covar glass.

[0011] Drawing 3 is drawing of longitudinal section of the photodetection tubing 1 concerning the gestalt of another operation. This photodetection tubing 1 is a photo-multiplier, and is equipped with the vacuum housing which closes upper limit opening of the glass bulb 12 with the face-plate 13 as an entrance window, and comes to close lower limit opening with the stem plate 14. The interior of this vacuum housing is decompressed rather than atmospheric pressure. In this vacuum housing, the photoelectric cathode 15 which carries out photo electric conversion of the light λ which penetrated the entrance window 13, and the metal anode plate 16 which collects the electrons e emitted from photoelectric cathode 15 are arranged. Moreover, between cathode 15 and an anode plate 16, the electron multiplier which consists of dynodes D1-D5 which carry out multiplication of the electron which carried out incidence is arranged in order.

[0012] Photoelectric cathode 15 is formed in the inside of an entrance window 13, predetermined potential is given to photoelectric cathode 15 through focusing electrodes 19 and 20, and potential higher than cathode 15 is given to dynodes D1-D5 and an anode plate 16. The thin film-like focusing electrode 19 is formed when metals, such as aluminum, are vapor-deposited by glass bulb 12 inside surrounding the space from the photoelectric cathode 15 to the dynode D1 of the 1st step, and the

tabular focusing electrode 20 consists of a metal plate with which a part of periphery contacted the thin film-like focusing electrode 19. The tabular focusing electrode 20 has opening in the center section. It connects with photoelectric cathode 15 electrically, and these focusing electrodes 19 and 20 form the electric field which converge the electron generated in photoelectric cathode 15 in the surrounded space by these with the dynode D1 of the 1st step into the 1st step dynode D1 arranged directly under [opening] a focusing electrode 20.

[0013] If it explains in full detail, a reference potential will be given to photoelectric cathode 15 and focusing electrodes 19 and 20 through the single lead pin 17, and such high potential will be given to dynodes D1-D5 and an anode plate 16 that it becomes the latter part through two or more remaining lead pins 17. For example, if touch-down potential is given to photoelectric cathode 15 and focusing electrodes 19 and 20, the potential of 100V is given to an anode plate 16 and the potential chosen as dynodes D1-D5 from the potential of 0-100V is given, the electric field which pull the electron e generated in photoelectric cathode 15 inside the vacuum housing according to the electrical potential difference between these in the anode plate 16 direction will occur.

[0014] After being accelerated according to an internal field, multiplication of the electron e generated in photoelectric cathode 15 according to the incidence of Light λ is carried out further, colliding, and multiplication being carried out to the dynode D1 of the 1st step, and carrying out a sequential collision rather than this at the latter dynodes D2-D5, and, finally it collides with an anode plate 16. The electron e collected in the anode plate 16 is taken out outside as the output current through the lead pin 17 electrically connected to the anode plate 16. In addition, the hermetic seal of the clearance between the lead pin 17 and the stem plate 14 is carried out by the charge 18 of a glass reinforcement.

[0015] This photo-multiplier is a photo-multiplier of a box and a grid mold, each dynodes D1-D5 are box molds, and the grid is prepared in the front face. Moreover, although the last stage dynode is arranged near the anode plate 16, it does not illustrate with the gestalt of this operation.

[0016] It has the photoelectric cathode 15 which carries out photo electric conversion of the light λ which the photomultiplier tube concerning the gestalt of this operation has been arranged the photoelectric tube concerning the gestalt of the above-mentioned implementation, the entrance window 13 which makes some vacuum housing outer walls similarly, and in a vacuum housing, and penetrated the entrance window 13, and an entrance window 13 consists of covar glass, and photoelectric cathode 15 consists of GaN. As mentioned above, covar glass makes the light more than the wavelength of about 290nm ($= \lambda_1$) penetrate alternatively, and GaN carries out photo electric conversion of the light below the wavelength of about 430nm ($= \lambda_2$) alternatively. therefore, this photomultiplier tube -- setting -- the wavelength of 360nm -- the peak of detection sensitivity -- having -- wavelength 360nm**-- only about 70nm light can be detected alternatively, without using an optical band pass filter.

[0017] In addition, although an above-mentioned entrance window and photoelectric cathode were applied to photodetection tubing of the head-on mold which has the photoelectric cathode of a transparency mold, these are also applicable to photodetection tubing which has the photoelectric cathode of a reflective mold, such as a photo-multiplier of a side-on mold, and an image intensifier.

[0018] Drawing 4 is drawing of longitudinal section of the photodetection tubing module 100 which has the above-mentioned photodetection tubing 1 inside. This photodetection tubing module is equipped with the envelopment cylinder 21 which contains the photodetection tubing 1, the cap member 22 which closes upper limit opening of the envelopment cylinder 21, and the closure plate 23 which closes lower limit opening of the envelopment cylinder 21. The cap member 22 has the through tube 24 drilled along with the longitudinal direction of the envelopment cylinder 21, and can lead the light λ from the module outside to the envelopment cylinder 21 interior through a through tube 24.

[0019] In the envelopment cylinder 21, the optical diffusion plates 25, such as an obscured glass which consists of an ingredient which makes the light of the above-mentioned specific wavelength penetrate at least, are arranged, and the optical diffusion plate 25 is located between the entrance window of the photodetection tubing 1, and the optical outgoing radiation edge of a through tube 24. The optical diffusion plate 25 is closing the optical outgoing radiation edge of a through tube 24, diffuses the light λ introduced in the through tube 24, and is irradiated in the direction of an

entrance window of the photodetection tubing 1. In addition, it can replace with the optical diffusion plate 25, an etching mesh can be arranged at the optical outgoing radiation edge of a through tube 24, and degradation of photoelectric cathode can also be prevented. The above-mentioned photodetection tubing 1 outputs an electrical signal according to the incidence of the light of specific wavelength. This electrical signal is amplified by the pre amplifier 26 arranged to the envelopment cylinder 21 interior, and is outputted outside through the lead wire which penetrates the closure plate 23. This photodetection tubing module can be used for the light source monitor for ultraviolet curing, the light source monitor for ultrapure water purification, etc.

[0020]

[Effect of the Invention] As mentioned above, as explained, according to photodetection tubing of this invention, only the light of specific wavelength can be detected without using an optical band pass filter, and photodetection can be performed to high sensitivity.

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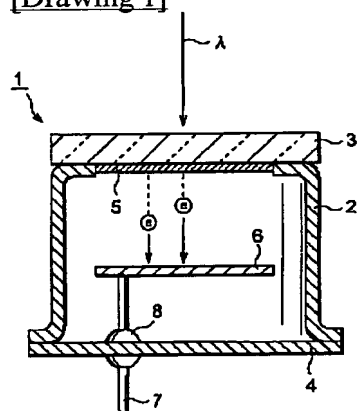
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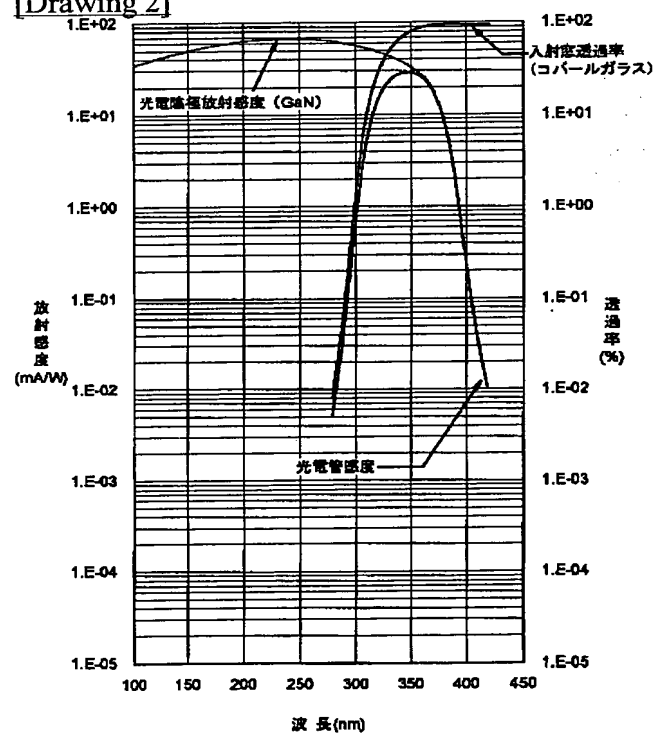
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DRAWINGS

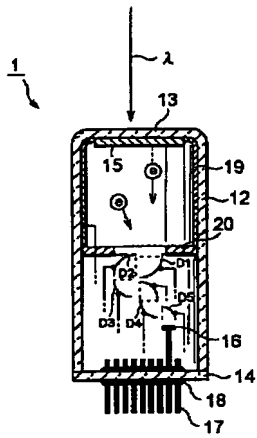
[Drawing 1]



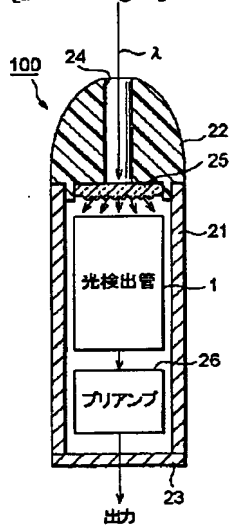
[Drawing 2]



[Drawing 3]



[Drawing 4]



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PHOTO-DETECTING TUBE

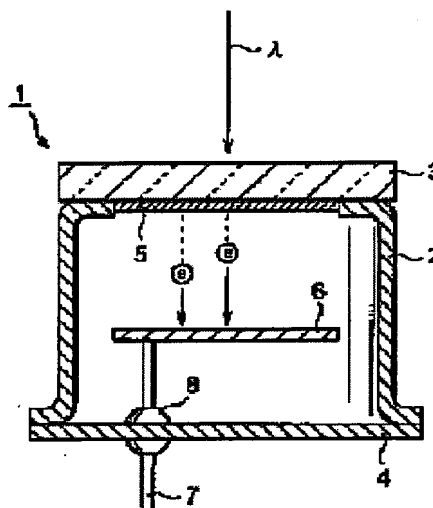
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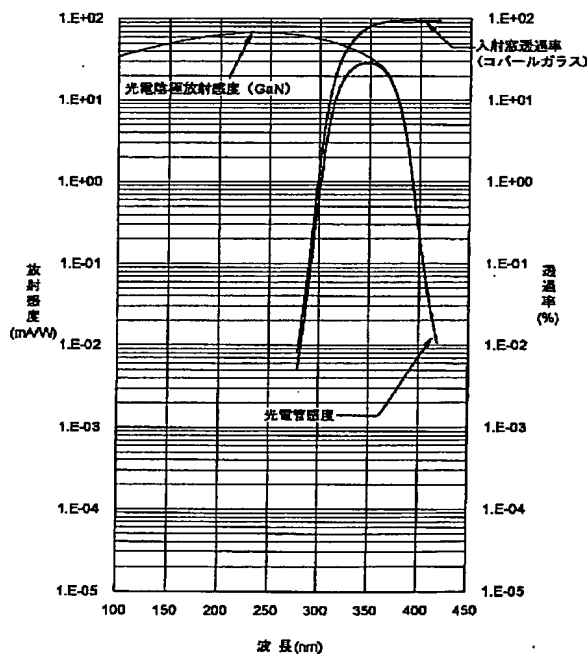
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(54) 【発明の名称】 光検出管

(57) 【要約】

【課題】 波長360nm付近の光のみを選択的に検出する光検出管を提供する。

【解決手段】 本光検出管1は、入射窓13及び光電陰極15を備えており、入射窓13はコパールガラスからなり、且つ、光電陰極15はGa Nからなる。コパールガラスは波長約290nm以上の光を選択的に透過させ、Ga Nは波長約430nm以下の光を選択的に光電変換する。したがって、本光検出管においては、波長360nmに検出感度のピークを有し、波長360nm±約70nmの光のみを光学的バンドパスフィルタを用いことなく選択的に検出することができる。



【特許請求の範囲】

【請求項1】 真空容器外壁の一部をなす入射窓と、前記真空容器内に配置され前記入射窓を透過した光を光電変換する光電陰極とを備えた光検出管において、前記入射窓はコパールガラスからなり、且つ、前記光電陰極はGa Nからなることを特徴とする光検出管。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、光電管や光電子増倍管等の光検出管に関する。

【0002】

【従来の技術】従来、光源の光強度を測定する光検出器として、半導体Siを用いたフォトダイオードが知られている。また、高感度の光検出を行う光検出器として光電子増倍管等の光検出管が知られている。

【0003】

【発明が解決しようとする課題】しかしながら、上述の光検出管においては、波長360nm付近の紫外光を射出する光源の強度をモニターする場合、その特定波長のみを透過させる透過率特性を有する光学フィルタを併用することを必要とした。すなわち、従来の光検出管においては光検出管前方に1又は2以上の特定波長光選択透過特性を有する光学フィルタを配置し、これを透過した光を検出していた。このような光学フィルタは、透過光の強度を減少させると同時に部品点数の増加を招いていた。本発明は、このような課題を解決するためになされたものであり、波長360nm付近の光のみを選択的に検出する光検出管を提供することを目的とする。

【0004】

【課題を解決するための手段】本発明に係る光検出管は、真空容器外壁の一部をなす入射窓と、真空容器内に配置され入射窓を透過した光を光電変換する光電陰極とを備えた光検出管において、入射窓はコパールガラスからなり、且つ、光電陰極はGa Nからなることを特徴とする。コパールガラスは波長約290nm以上の光を選択的に透過させ、Ga Nは波長約430nm以下の光を選択的に光電変換する。したがって、本光検出管においては、波長360nm±約70nmの光のみを光学的バンドパスフィルタを用いることなく選択的に検出することができる。

【0005】

【発明の実施の形態】以下、実施の形態に係る光検出管について説明する。同一要素又は同一機能を有する要素には同一符号を用いるものとし、重複する説明は省略する。

【0006】図1は、実施の形態に係る光検出管1の縦断面図である。本光検出管1は光電管であり、金属製側管2の上端開口部を、入射窓としての面板3で封止し、下端開口部をステム板4で封止してなる真空容器を備える。本真空容器の内部は大気圧よりも減圧されている。

本真空容器内には、入射窓3を透過した光λを光電変換する光電陰極5と、光電陰極5から放出された電子eを収集する金属製の陽極6とが配置されている。

【0007】光電陰極5は入射窓3の内面に形成されており、光電陰極5には側管2を介して所定の電位が与えられ、陽極6には陰極5よりも高い電位が与えられる。例えば光電陰極5を接地し、陽極6に100Vの電位を与えると、これらの間の電圧に従って真空容器内部に電子eを陽極6方向へ引っ張る電界が発生する。光λの入射に応じて光電陰極5で発生した電子eは、内部電界にしたがって加速された後、陽極6に衝突し、陽極6に電気的に接続されたリードピン7を介して出力電流として外部に取りだされる。なお、リードピン7とステム板4との間の隙間はガラス充填材料8によって気密封止されている。

【0008】図2は、波長-入射窓透過率(%)特性、波長-光電陰極放射感度(mA/W)特性、及びこれらを合成した光電管1自体の検出感度(mA/W)特性を示すグラフである。入射窓3に入射した光λのうち、波長λ₁以上の成分は入射窓3を透過する。また、光電陰極5に入射した光λのうち、波長λ₂以下の成分は光電陰極5によって光電変換される。波長λ₂は波長λ₁よりも長く、したがって、光電管1自体は、波長λ₁~λ₂の間に検出感度を有する。

【0009】なお、入射窓3の波長λ₁における透過率は波長λ₁+140nmにおける透過率の約1/1000以下であり、光電陰極5の波長λ₂における放射感度は波長λ₂-140nmにおける放射感度の約1/1000以下である。

【0010】本実施の形態に係る光電管1は、真空容器外壁の一部をなす入射窓3と、真空容器内に配置され入射窓3を透過した光λを光電変換する光電陰極5を備え、入射窓3はコパールガラスからなり、且つ、光電陰極5はGa Nからなる。コパールガラスは波長約290nm(=λ₁)以上の光を選択的に透過させ、Ga Nは波長約430nm(=λ₂)以下の光を選択的に光電変換する。したがって、本光電管においては、波長360nm付近に検出感度のピークを有し、波長360nm±約70nmの光のみを光学的バンドパスフィルタを用いることなく選択的に検出することができる。また、本光電管の検出感度のピーク値を与える波長360nm±約70nmにおけるそれぞれの検出感度は、ピーク値の検出感度の約1/1000以下である。また、本光電管の波長254nmにおける検出感度は、ピーク値の検出感度の約1/1000以下であり、水銀ランプの波長360nmの光を波長254nmの光と区別して検出することができる。なお、本コパールガラスは、日本電気真空硝子(株)社製のコパ-硬質ガラス(KB硬質ガラス)を用いた。

【0011】図3は、別の実施の形態に係る光検出管1

の縦断面図である。本光検出管1は光電子増倍管であり、ガラスバルブ12の上端開口部を、入射窓としての面板13で封止し、下端開口部をステム板14で封止してなる真空容器を備える。本真空容器の内部は大気圧よりも減圧されている。本真空容器内には、入射窓13を透過した光λを光電変換する光電陰極15と、光電陰極15から放出された電子eを収集する金属製の陽極16とが配置されている。また、陰極15と陽極16との間には入射した電子を増倍するダイノード $D_1 \sim D_n$ からなる電子増倍器が順番に配置されている。

【0012】光電陰極15は入射窓13の内面に形成されており、光電陰極15には集束電極19、20を介して所定の電位が与えられ、ダイノード $D_1 \sim D_n$ 及び陽極16には陰極15よりも高い電位が与えられる。薄膜状集束電極19は光電陰極15から第1段目のダイノード D_1 までの空間を囲むガラスバルブ12内面にアルミ等の金属が蒸着されることによって形成され、板状集束電極20は外周の一部分が薄膜状集束電極19に接触した金属板からなる。板状集束電極20は中央部に開口を有している。これらの集束電極19、20は、光電陰極15に電氣的に接続されており、第1段目のダイノード D_1 と共に、これらによった囲まれた空間内に光電陰極15で発生した電子を集束電極20の開口直下に配置された第1段ダイノード D_1 内に集束させる電界を形成する。

【0013】詳説すれば、光電陰極15及び集束電極19、20には単一のリードピン17を介して基準電位が与えられ、ダイノード $D_1 \sim D_n$ 及び陽極16には、残りの複数のリードピン17を介して後段になるほど高い電位が与えられる。例えば光電陰極15及び集束電極19、20に接地電位を与え、陽極16に100Vの電位を与え、ダイノード $D_1 \sim D_n$ に0～100Vの電位から選択される電位を与えると、これらの間の電圧に従って真空容器内部に光電陰極15で発生した電子eを陽極16方向へ引っ張る電界が発生する。

【0014】光λの入射に応じて光電陰極15で発生した電子eは、内部電界にしたがって加速された後、第1段目のダイノード D_1 に衝突して増倍され、これよりも後段のダイノード $D_2 \sim D_n$ に順次衝突しながらさらに増倍され、最終的に陽極16に衝突する。陽極16で収集された電子eは、陽極16に電氣的に接続されたリードピン17を介して出力電流として外部に取りだされる。なお、リードピン17とステム板14との間の隙間はガラス充填材料18によって気密封止されている。

【0015】本光電子増倍管は、ボックスアンドグリッド型の光電子増倍管であり、各ダイノード $D_1 \sim D_n$ はボックス型であって、その前面にはグリッドが設けられている。また、陽極16の近傍には最終段ダイノードが配置されているが、本実施の形態では図示しない。

【0016】本実施の形態に係る光電子増倍管は、上記

実施の形態に係る光電管と同様に、真空容器外壁の一部をなす入射窓13と、真空容器内に配置され入射窓13を透過した光λを光電変換する光電陰極15とを備え、入射窓13はコパールガラスからなり、且つ、光電陰極15はGa Nからなる。上述のように、コパールガラスは波長約290nm($=\lambda_1$)以上の光を選択的に透過させ、Ga Nは波長約430nm($=\lambda_2$)以下の光を選択的に光電変換する。したがって、本光電子増倍管においては、波長360nmに検出感度のピークを有し、波長360nm±約70nmの光のみを光学的バンドパスフィルタを用いることなく選択的に検出することができる。

【0017】なお、上述の入射窓及び光電陰極は、透過型の光電陰極を有するヘッドオン型の光検出管に適用したが、これらは反射型の光電陰極を有するサイドオン型の光電子増倍管やイメージインテンシファイア等の光検出管に適用することもできる。

【0018】図4は、上記光検出管1を内部に有する光検出管モジュール100の縦断面図である。本光検出管モジュールは、光検出管1を収納する包囲筒21と、包囲筒21の上端開口部を封止するキャップ部材22と、包囲筒21の下端開口部を封止する封止板23とを備える。キャップ部材22は、包囲筒21の長手方向に沿って穿設された貫通孔24を有しており、モジュール外部からの光λを貫通孔24を介して包囲筒21内部に導くことができる。

【0019】包囲筒21内には上記特定波長の光を少なくとも透過させる材料からなるスリガラス等の光拡散板25が配置されており、光拡散板25は光検出管1の入射窓と貫通孔24の光出射端との間に位置する。光拡散板25は貫通孔24の光出射端を封止しており、貫通孔24内に導入された光λを拡散して光検出管1の入射窓方向へ照射する。なお、光拡散板25に代えてエッチングメッシュを貫通孔24の光出射端に配置し、光電陰極の劣化を防止することもできる。上述の光検出管1は、特定波長の光の入射に応じて電気信号を出力する。この電気信号は包囲筒21内部に配置されたブリアンプ26で増幅され、封止板23を貫通するリード線を介して外部に出力される。本光検出管モジュールは、紫外線硬化用光源モニターや超純水精製用光源モニター等に用いることができる。

【0020】

【発明の効果】以上、説明したように、本発明の光検出管によれば、特定波長の光のみを光学的バンドパスフィルタを用いることなく検出することができ、高感度に光検出を行うことができる。

【図面の簡単な説明】

【図1】実施の形態に係る光電管の縦断面図。

【図2】波長-入射窓透過率(%)特性、波長-光電陰極放射感度(mA/W)特性、及びこれらを合成した光

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電管1自体の検出感度特性を示すグラフ。

* 面図。

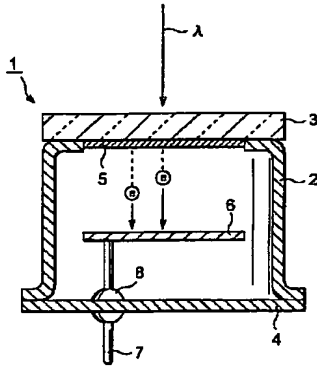
【図3】実施の形態に係る光電子増倍管の縦断面図。

【符号の説明】

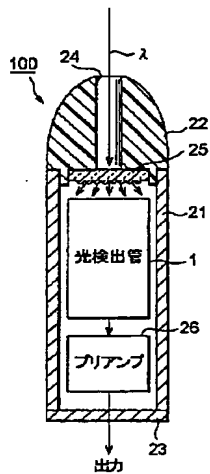
【図4】光検出管を内蔵した光検出管モジュールの縦断*

1…光検出管、13…入射窓、15…光電陰極。

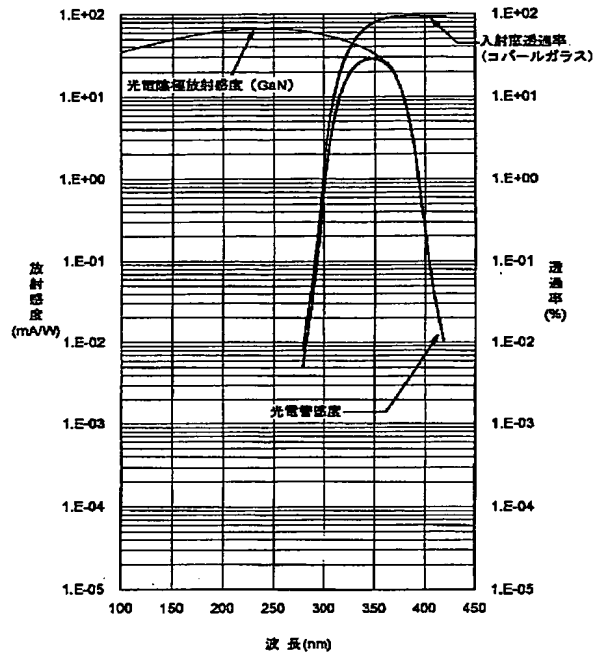
【図1】



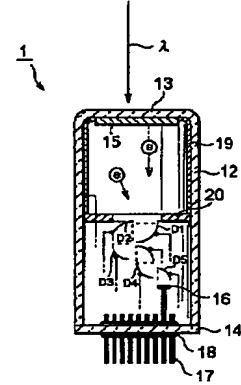
【図4】



【図2】



【図3】



フロントページの続き

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